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EXPLORATION OF THE REASONS FOR DELAYS IN CONSTRUCTION

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Abstract:

Construction sites are dominated by chaos and complexity enforcing challenging conditions for establishing reliable and robust schedules that are easy to observe. The consequence is a large amount of delayed activities that again results in an unreliable schedule. Last Planner System (LPS) was introduced as a production planning and control system to increase the reliability of scheduling task. By focusing on the removal of constraints, LPS has successfully decreased the number of delayed activities. To further decrease delays, this research investigates causes for delays at three construction cases. In total 5424 scheduled activities were followed, whereof 1450 was delayed. The delayed activities were besides unidentified categorized into 11 different categories and a statistical test of means was performed. The research revealed six often-occurring causes to delay: connecting work, change in work plans, workforce, external conditions, material, and construction design. Furthermore, the study revealed five seldom-occurring causes to delay: space, equipment, rework, unexpected conditions, and safety. The findings have been structured in accordance to the preconditions used in the LPS theory. Therefore, the results can directly be applied to the making ready process and used as guidance of where to intervene in attempt to reduce future delay..

Keywords:
Constraints, Last Planner System, Lean Construction, Preconditions, Scheduling

1 INTRODUCTION

Last Planner System (LPS) is a production planning and control system developed in an attempt to increase the reliability of the schedule which could lead to increased productivity at the construction site (Gonzarlez *et al.* 2008). The need for an improved schedule was exposed in a case study conducted by Howell and Ballard (1995). They find that only approximately half of the activities in a schedule are completed on schedule (Ballard 1999; Howell and Ballard 1995). Further, a study by Howell and Ballard validates the results, and shows that only 35-65 percent

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of the planned activities are completed (PPC) as scheduled (Ballard and Howell 1998; Ballard 1997).

LPS consists of four primary schedules: 1) The Master Schedule containing milestones, 2) The Phase Schedule which secures the right sequence of the work, 3) The Look-ahead Plan where constraints are removed and activities are made ready for conduction, and 4) The Weekly Work Plan containing the subcontractors' commitments to which activities are to be conducted the upcoming week. To secure reliability of the schedule only activities made ready for work are selected (Ala-Risko and Kärkkäinen 2006). Finally, LPS contains the PPC measurement which is a feedback and learning system. Here, root causes for delayed activities are investigated and afterwards eliminated (Lindhard and Wandahl 2012b).

The purpose of the Look-ahead Plan is to increase the reliability of the schedule. Look-ahead planning is conducted as a 5 week planning frame from the Master Plan, containing a planning frame between 3-12 weeks ahead. Each week the planning frame slides one week forward (Ballard 2000). The length of the Look-ahead Window depends on the necessary duration of the making-ready process, the reliability of the plans, and project characteristics (Ballard 2000).

In the Look-ahead frame the making-ready process proceeds and constraints for conducting each activity are removed to secure the soundness of each activity. Only sound activities are afterwards selected to the Weekly Work Plan (Hamzeh *et al.* 2008; Steyn 2001). Thus, LPS does opposite traditional scheduling not focus alone on when an activity should be finished but also on when it can be finished (Chua and Shen 2005). By ensuring only sound activities are selected the success rate of tasks completed on schedule is together with PPC measurement increased radically (Jang and Kim 2008).

To secure soundness, constraints have to be removed to avoid delayed activities. Koskela (Koskela 1999) found that soundness depends on seven preconditions. If just one precondition is not fulfilled the activity cannot be conducted. Therefore, it is extremely important that assignments do not miss any of the seven constraints. The seven preconditions are as follows:

1. Construction design; correct plans, drafts and specifications are present
2. Components and materials are present
3. Workers are present
4. Equipment and machinery are present
5. Sufficient space to execute the task
6. Connecting works, previous activities must be completed
7. External conditions must be in order.

In a later study conducted by Lindhard and Wandahl (2012a) the preconditions are expanded by splitting "external conditions" into three categories ending up with nine key categories. The "external conditions" category covers several fundamentally different subcategories. Putting a

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name on the specific subcategories brings increased awareness and attention to the preconditions. This helps the site-manager to trace any remaining constraints. External conditions are divided into the following:

7. Climate conditions must be acceptable.
   The preconditions focus on external environmental effects such as rain, snow, wind, heat, cold etc.
8. Safe working conditions must be present.
   The precondition secures that the national “Health and Safety at Work Act” is obeyed keeping the employees safe.
9. The surrounding conditions must be known.
   The precondition focus on securing that existing conditions, if necessary, are examined. Problems often arise during excavations or refurbishment assignments.

The implementation of LPS has been proven successful and through case studies a relationship between application of LPS and increased project performance has been indicated. Furthermore, improvements have been reported in plan reliability, project delivery time, and labor productivity (Alsehaimi *et al.* 2009; Formoso and Moura 2009; Friblick *et al.* 2009; Alarcón *et al.* 2005; Garza, Jesus M. de la and Leong 2000).

Even though increased PPC has been gained after implementing LPS, a more reliable and robust schedule is still needed (Ballard 2000). Implementation of LPS has been successful in raising PPC to the 70% level. But the PPC level is right now stuck at the 70% level. In order to reach the 90% level or higher, additional actions are required (Seppänen and Aalto 2005; Ballard 2000)
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To help site management in reaching a higher PPC level, it is important to understand the causes of delays. A number of research studies have examined reasons to delay. Sambasivan and Soon (2007) did from a questionnaire survey of 150 participants identified 26 reasons to delay at project level which resulted in time overrun, disputes, arbitration, ligitation, and total abandonment these effects have been supported by Ibironke *et al.*(2013). According to Sambasivan and Soon (2007) is the top ten reasons to delay listed from top to low: Contractor’s improper planning, contractor’s poor site management, inadequate contractor experience, inadequate client’s finance and payments for completed work, problems with subcontractors, shortage in material, labor supply, equipment availability and failure, lack of communication between parties, and mistakes during the construction stage. AlSehaimi et al. (2009) identified 17 reasons to incomplete assignments, the top ten from high to low being: prerequisite work, materials, approvals, change in priority, labour, equipment, design, submittals (late request), over estimate of achievements, and incomplete information. Mitropoulos and Nichita (2010) identified 6 reasons to plan failures; from high to low the reasons were: prerequisite work, labor

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availability, quality, material, change of priorities, and weather. Moreover Mitropoulos and Nichita (2010) found that plan failures were caused by a combination of labor shortage, high workload, and quality problems and finds that improved reliability of work tasks and reducing quality failures are critical in order to reduce plan failures in on-site production. Exactly work task reliability has a strong focus in LPS. Despite the studies provides an insight to the delay causes, none of the studies above related the findings to the making ready process or the preconditions presented above. By identifying failure rates in relation to preconditions the results can directly be applied in LPS to determine where and how to intervene to improve the making ready process and from this prevent delays from occurring. In other terms, in the search of continuous improvement, this research aims in this case study is to disclose root causes to delay and identify the distribution categorized in accordance with Lean Constructions preconditions to sound work tasks. The research question is:

What reasons to delay can be found in activities completed in on-site construction?

2 RESEARCH METHOD

The research question is examined through multiple case studies. Three Danish construction sites were followed focusing on observing reasons for delayed activities. The case studies took place in year 2011 to 2012. The number of cases is considered to give “theoretical saturation” (Eisenhardt 1989; Romano 1989). A clear focus is in particular important when conducting case studies. With a clear research focus the right data can be identified instead of collecting overwhelming volumes of data (Eisenhardt 1989). Therefore, Mintzberg (1979) states *"No matter how small our sample or what our interest, we have always tried to go into organizations with a well-defined focus - to collect specific kinds of data systematically."*

The research was conducted as a triangulation of qualitative and quantitative research methods. An advantage of using a qualitative approach is that the study is viewed in relation to its context (Yin 2003). By understanding the context an underlying appreciation of the problem is gained. Furthermore, processes are influenced by the surrounding context (Hartley 2004). In every case multiple observations are collected resulting in a qualitative data collection. The quantitative approach secures a statistical validity of the collected data. Data is collected mainly through archives (e.g. meeting minutes) and contains summaries from LPS meetings, and actual meeting participation. An LPS meeting is in lean construction projects conducted every Friday, where all foremen plan the following week’s activities. The outcome of this meeting is mainly the Weekly Work Plan, but also an evaluation, in terms of the PPC measure along with observed reasons for delays, of last week’s activities is conducted.

Two basic selection criteria were applied when selecting cases, namely A).Last Planner had to be implemented, and B) PPC calculation had to be conducted. Because data was collected mainly from archived summaries, it was required that reasons for non sound activities and

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delays were collected and described. To secure consistency the site manager was the same person on all construction projects. In the selection process, mail correspondences and phone conversations with company consultants and site managers secured the fulfillment of the requirements.

The three case studies were based on guidelines presented in Eisenhardt (1989). Data from the entire construction period was collected from archives. To ensure that LPS was correctly applied the archive data was in one construction case supplemented with on-site observation, meeting participation, and semi and unstructured interviews with the site manager. Since all cases had the same site manager in charge, insight in the scheduling process from all projects was achieved. Data collected from the three cases is listed in Table 1 which is followed by a short case description.

Table 1. Data collected from the three case-studies.

	Case 1	Case 2	Case 3
Contract form	Turnkey contractor	Turnkey contractor	General contractor
Project followed	Entire construction period	23 weeks	Entire construction period
From archives	Reports from LPS meetings	Reports from LPS meetings	Reports from LPS meetings
Construction period	65 weeks	23 weeks	60 weeks
Activities registered	2239 activities	593 activities	2592 activities
Delayed activities	746 activities	134 activities	570
Average PPC	66.7 %	77.4 %	78.0 %

2.1 Case I – Educational institution

Case one was construction of an educational institution. The project consisted of two buildings, in total 11000 m^2. The main building was a three-storey building plus basement, in total 8000 m^2, while the secondary building was a two-storey building with no basement, in total 3000 m^2. In total the contract value for both buildings was estimated to US$29 million. Furthermore, the construction period was restricted to only 16 months.

2.2 Case II – Educational institution

Case two was a renovation project of an educational institution involving only renewal of the roofing. As the renovation progressed extra work was added to the original project. Additional work was accumulated to renovation of windows, inner walls, and sewers. In total the project contract value ended at US$5 million, with a fixed schedule of 9 months.

2.3 Case III – Housing

Case three was a renovation project of nine residential apartment blocks. The blocks contained a total of 300 flats distributed on 32 stairways. Because of variation in storeys and size, the flats

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were irregular distributed between the blocks. The contract included renovation of facade and renewal of the roofing. The project contract value was US$29 million, with a duration fixed at 25 months.

3 RESULTS

Three construction cases were followed to detect causes to delays in onsite construction. In total 5424 activities were registered whereof 1450 were not completed according to schedule. The 1450 registrations of delay have been divided into 11 different root-causes. However, in 612 of the activities the cause to delay was not identified. This is a consequence of the research approach, where the data mainly is derived from summaries from scheduling meetings. In 612 incidents the registration was insufficient. The results are presented in Table 2 where the three cases are compared. In the first column the actual registrations are stated, while the second column contains the registration of incidents per 100 planned activities. This calculation makes a comparison between the results possible.

The results are, besides the "unidentified" category, divided into 11 categories. Nine of the categories contain delays caused by having not-ready activities in the Weekly Work Plans. These nine categories correspond to the nine preconditions presented earlier. The remaining two categories contain delays caused by changes made in the schedule or activities where rework is required. The two categories is corresponding to the change of priorities and quality categories identified by Mitropoulos and Nichita (2010).

A quick glance at Table 2 shows similarities in the results from case to case, i.e. the distribution differs only little. The consistency is in particularly strong with the seldom-occurring causes to delays, i.e. equipment, space, safety, unexpected conditions, and rework. Finally, Table 2 reveals that approximately 25-30% of all scheduled activities are eventually delayed.

Table 2. A comparison of results between the three case studies.

	Case I		Case II		Case III	
	Registrations of occurrences	Registrations p. 100 planned activities	Registrations of occurrences	Registrations p. 100 planned activities	Registrations of occurrences	Registrations p. 100 planned activities
Unidentified	286	12.77%	61	10.29%	265	10.22%
Connecting works	170	7.60%	12	2.02%	68	2.62%
Change in work plans	60	2.68%	11	1.86%	76	2.93%
Work force	56	2.50%	6	1.01%	72	2.78%
Weather conditions	29	1.30%	13	2.19%	50	1.93%
Materials	53	2.37%	18	3.04%	16	0.62%

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Construction design	56	2.50%	8	1.34%	12	0.46%
Space	16	0.71%	2	0.34%	3	0.12%
Rework	12	0.53%	0	0.00%	1	0.04%
Equipment	5	0.22%	0	0.00%	3	0.12%
Unexpected conditions	1	0.04%	2	0.34%	3	0.12%
Safety	2	0.09%	1	0.17%	1	0.04%
Total	746	33.32%	134	22.60%	570	22.00%

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The data collection consists of a weekly registration of delays in the three construction cases. By looking at the weekly percentage-wise allocation it is possible to test the results. To perform a T-test of means the registrations are grouped in clusters of three weeks. Hence, the three-week mean, which appears in
, is a calculation of the percentage-wise frequency in relation to the total scheduled activities in a three-week period. The three-week period is necessary to secure that a single registration will not induce a significant deviation in the results.

A two-tailed T-test was applied to test for means with a significance level of p=0,05. The calculated confidence interval represents the interval, within which the observed mean with a likelihood of 95% would be situated. The actual interval is shown in the column named “Interval of population mean”. Hence, delays related to construction design would with an accuracy of 95% lie within the range of]0.86; 1.93] percentage of the scheduled activities in a three week period. The small standard deviation and standard error calculated in Table 3 validates the results.

Table 3. Comparison of statistic measures, standard deviation, standard error and the result from the applied T-test.

					One sample T-test	
	Number of registrations	3 week Mean	Standard deviation	Standard Error of Mean	95% Confidence Interval of population mean	Interval of population mean
Unidentified	612	9.35	4.07	0.64	± 1.28	]8.06; 10.63]
Connecting works	250	3.81	3.13	0.49	± 0.99	]2.82; 4.79]
Change in work plans	147	2.41	1.64	0.26	± 0.52	[1.89; 2.93[
Work force	134	2.19	1.98	0.31	± 0.63	]1.56; 2.81]
Weather conditions	92	1.88	2.06	0.32	± 0.65	[1.23; 2.53[
Components and materials	87	1.63	1.93	0.30	± 0.61	]1.02; 2.24[
Construction design	76	1.39	1.70	0.27	± 0.54	]0.86; 1.93]
Space	21	0.39	0.78	0.12	± 0.25	]0.14;0.63]
Rework	13	0.15	0.42	0.07	± 0.13	[0.02; 0.29[
Equipment and machinery	8	0.11	0.27	0.04	± 0.09	]0.02; 0.19]
Unexpected conditions	6	0.16	0.51	0.08	± 0.16	]0.00; 0.32]
Safety	4	0.08	0.27	0.04	± 0.09	]-0.01; 0.17[
Total	1450	23.55	--	--	--	--

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4 DISCUSSION

Delay is a tangible problem in on-site construction. Thus there is a need for an increased robustness of the schedule. In the three construction cases investigated the average PPC ended at 74.03%. From this follows that 25.97% of the scheduled activities are not completed on schedule and ends up as being delayed. Therefore, causes to delay have been registered in order to understand the problem that on-site production is facing and thereby pursuing even higher PPC levels. However, this is only regarded as the first step in the learning process. More in-depth research needs to be carried out to find the underlying root causes.

Of cause the high frequency of activities where the cause is not determined affects the results. Several explanations or distributions of the "unidentified" category can exist: A) The "unidentified" category can be caused by not identified categories or sources to delay; B) The "unidentified" category could be delays related to a single or few categories were the registrations have not been correctly completed; C) The "unidentified" category contains common mistakes in the registration process, and should be equally distributed between all the identified categories; D) Finally the "unidentified" category could be caused by a combination of A), B) and C).

The registration process has been directly observed which revealed that even though it was not registered, poor estimates of durations caused delays. Moreover, it was observed that unidentified registrations seem to be occurring when the time restrictions are causing the registration process to be accelerated. Accelerating work by skipping parts of the scheduling and preplanning tasks can be one of the reasons to why Mitropoulos and Nichita (2010) identified high-workload as a one of three key reasons to planning failure (the others being labour shortage and quality problems). It is not suspected that the distribution of causes within the "remaining" unidentified registrations is different from the ones observed. Therefore, the distribution among the causes would be very close to the one presented. Though the effect would be that the frequency per 100 scheduled activities goes up which changes the calculated "Intervals for population mean", see Table 3. For instance the frequency of delays caused by "connecting works" will be between 250 and 433 incidents depending on the number of unidentified registrations caused by poor estimates of duration.

Furthermore, the direct observations revealed that every delayed activity is registered in only one category, even though multiple causes can affect the completion process simultaneously. Again the missing registrations can be related to explanation A) B) or C) confer the distribution of the "unidentified" category. Since no pattern was identified, the missing registrations are assessed equally distributed between the categories. Still, a more comprehensive registration of causes will increase the frequency of incidents in the identified categories.

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The results revealed six often-occurring causes to delays respectively: connecting work, change in work plans, workforce, weather conditions, material, and construction design. Furthermore, the results revealed five seldom-occurring causes to delays respectively: space, rework, equipment, unexpected conditions, and safety. Finally, when looking at results from the three cases separately, there was consistency between the low at high-frequency causes to delays.

It is important to state that the consequence of a delayed activity is connected to both frequency and impact. Impact includes the direct cost which is the direct measurable consequence and indirect cost which is uncountable and related to cost at either project, at individual, or at organizational level (Love 2002). The indirect consequence, which is much larger than the direct consequence, is estimated through a determined distribution of cost (Love 2002; Love and Li 2000; Burati *et al.* 1992). Therefore, it is very difficult to measure the total impact and consequence of a delayed activity.

Impact is individual for each delay and will vary. Since impact has not been registered it is impossible to state if patterns exist in impact. To do so further research needs to be carried out. If patterns are discovered it could help managers in deciding where to intervene. Even though the impact is not known the results can still be used as guidance on where to intervene. The greatest effect, in relation to decreasing the number of delays, would be gained by focusing on preventing the often-occurring causes. Therefore, since the impact is unknown, it would be rational to focus on preventing the high-frequency causes.

When looking at the result two findings stand out. 1) That the most frequent cause to delay is related to connecting works. The finding is supported by both (Mitropoulos and Michita 2010; AlSehaimi *et al.* 2009) which indicates that delays are too easily transmitted from one activity to another. One reason could be that the sounding process, implemented to secure reliability in the schedule, is not applied correctly. According to the sounding process only activities where all preconditions are removed are allowed to be transferred to the Weekly Work Plans. This corresponds with the findings by Lindhard and Wandahl (2012b) who find that activities with remaining constraints are allowed to enter the Weekly Work Plan. Furthermore, it could be a good idea to implement a buffer between critical handoffs.

2) How often the Weekly Work Plans change. The changes might have a different nature but the root cause would most likely be a complex and changing environment, which forces the schedule to be rethought to optimize the output. Even so a changing Weekly Work Plan is not desirable. A schedule should be robust, reliable and trustworthy, and most importantly binding for all partners. If the schedule is continually changed it loses its credibility. Orders are no longer clear and simple, and changes cause confusion that can lead to misunderstandings. A changing schedule can affect how contractors and craftsmen understand the schedule. Instead of commitments to a fixed deadline, it could now be understood more as guidance.

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Furthermore, a changing schedule can create a "*separation of execution from planning*" (Koskela and Howell 2001). This phenomenon occurs when the contractors neglect the project's plans and schedules and instead work towards own priorities. It has previously been recorded as caused by unreliable scheduling and is followed by increased conflicts and delays which lead to low productivity (Koskela and Howell 2001). Thus, if a "separation of execution from planning" happened at the followed construction sites delays can simply be caused by commitments not being kept because the subcontractors work with own priorities.

Finally, it is important to state that the distribution of delay in relation to the 11 categories presented may vary noticeably depending on the type of construction project for instance offshore, road, refurbishment, housing etc.

5 CONCLUSION AND FURTHER RESEARCH

Three case studies were conducted in order to determine the different causes to delays in activities in construction. The research was limited to look at the frequency of delayed activities; further research could look at impact. Here, patterns could help mangers to decide where to intervene. The studies revealed besides the "unidentified" in total 11 different causes to delay. Six of them were often occurring causes respectively: connecting work, change in work plans, workforce, external conditions, material, and construction design. Furthermore, five were seldom occurring causes revealed respectively: space, rework, equipment, unexpected conditions, and safety.

Through a statistical analysis, it was found that connecting works was the most frequent cause to delay. With a likelihood of 95% delay caused by problems with connecting works would occur between]2.82; 4.79] per 100 scheduled activities. The findings could indicate that the making ready process in Last Planner System is misusage for instance by including unsound activities in the Weekly Work Plans.

The findings revealed a high number of changes in work plans, with a likelihood of 95% delay caused by problems with connecting works would occur between [1.89; 2.93[per 100 scheduled activities. A changing schedule is not desirable since the schedule should be reliable and binding. Orders are no longer clear and simple, and changes cause confusion that can lead to misunderstandings. Furthermore, it could have a negative effect on the schedules credibility where the schedule no longer is understood as a fixed deadline but just as guidance.

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